NAVAL SUBMARINE MEDICAL RESEARCH LABORATORY

SUBMARINE BASE, GROTON, CONN.

REPORT NUMBER 1108

VISUAL SENSITIVITIES UNDER REDUCED OXYGEN

by

S. M. Luria and Nancy Morris

Released by:

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Commanding Officer
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SUMMARY PAGE

PROBLEM

To determine the effects of lowered concentrations of oxygen in an artificial atmosphere on night vision sensitivity and field-of-view.

FINDINGS

Reductions in the percentage of oxygen in the breathing mixture to 13% (compared to 21% in air at sea-level) did not impair visual performance.

APPLICATION

Visual performance is not expected to be degraded by the typical reductions in oxygen level which often occur in submarines. These results suggest that, as far as night-vision and field-of-view are concerned, much greater reductions in the oxygen level can be tolerated by the submarine crew.

ADMINISTRATIVE INFORMATION

This research was conducted as part of the Naval Medical Research and Development Command Work Unit entitled, "Crew responses to 19% oxygen in the atmosphere of nuclear submarines." It was submitted for review on 16 October 1987, approved for publication on 27 January 1988, and designated as NSMRL Report No. 1108.

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Visual Sensitivities under Reduced Oxygen

S.M. Luria and Nancy Morris

ABSTRACT

Thirteen subjects were confined in a hypobaric chamber for 15 days, and their scotopic sensitivity and field-of-view were measured twice a day. The oxygen concentration in the nitrogen-oxygen atmosphere was changed every three days in this sequence: 21%, 17%, 21%, 13%, and 21%. The barometric pressure was always equivalent to sea-level, except for the final 7 hours of exposure to 17% oxygen when it was reduced to 576 torr. The atmosphere was contaminated with 0.9% carbon-dioxide throughout the confinement. Neither visual function was degraded by the lowered oxygen levels. Keywords: submarines; naval personnel; performance (human); hypoxia; night vision; field of vision; (KT)

The submarine is a closed environment. The atmosphere is constantly being treated--"scrubbed" is the submariner's term--in an attempt to maintain the oxygen level at the normal sea-level proportion of 21%. Sensors constantly monitor the atmospheric constituents and display the data which are regularly checked and recorded. The oxygen level is often less than 21%, sometimes dropping below 19%. The question immediately arises, does this decrease in the oxygen level affect performance?

The Naval Submarine Medical Research Laboratory in collaboration with the Army Research Institute of Environmental Medicine has tested the effects of 13 and 17% oxygen on physiological and psychological performance. This report presents the results of one facet of that investigation, the effects of hypoxia on night vision sensitivity and field of view.

METHOD

General Procedure

The study was carried out in two phases, because the hypobaric chamber could not accommodate the full complement of subjects at one time. Six subjects completed the study during the first phase, and seven subjects completed the second phase.

After two practice sessions a day for a week, the subjects were sealed in the hypobaric chamber for 15 days. The oxygen level was 21% for an initial period, after which it was changed by the chamber operators according to a preset schedule. Three oxygen levels, all at normal barometric pressure, were tested, 21%, 17% and 13%, according to the following schedule: The oxygen level during the first three days of confinement was 21%; it was 17% for the next three days, 21% for the next three days, 13% for the next three days, and 21% for the final three days. In addition, during the last seven hours of the 17% condition, the barometric pressure was reduced to 576 torr. This was done to simulate the partial vacuum caused by a the occurrence of a "high vacuum diesel shutdown". The oxygen levels were changed without the knowledge of the subjects. Under each oxygen condition, they were tested twice a day on the first day, on the afternoon of the second day, and twice on the third day.

Scotopic Sensitivity

The subjects were first dark-adapted by wearing light-proof goggles for 20 minutes. They were then led into the light-proof viewing-chamber where they occluded the left eye with an eyepatch, put on a headset to communicate with the experimenter, and positioned their heads in a chinrest. This positioned their eye 60 cm from a ground-glass screen on which was projected a circle of light subtending 0.5 deg visual angle. This was presented 10 deg to the left of a pin-point red fixation light and flickered 2 cps to facilitate recognition. The light source was a projection bulb whose dominant wavelength was adjusted to slightly less than 500 nm with a Corning glass filter and whose intensity was varied with neutral density filters. The luminances were measured with a Spectra Pritchard Photometer, Model 1980, and the spectral distribution was measured with a Photo-Research PR-703A "Spot Spectrascan" spectro-radiometer.

To measure scotopic sensitivity, a series of five or six intensities at 0.1 neutral density intervals was first chosen. Thresholds were then measured with the Method of Constant Stimuli. Each intensity was presented in random order from six to 10 times, depending on the subject's variability. Subjects were cautioned that a light would not be presented every time and to avoid guessing. The frequency with which each intensity was seen was calculated and that relationship plotted on cumulative probability paper. The threshold was that intensity seen 50% of the time.

Perimetry

The perimetric apparatus was a semi-circular band of aluminum, 70 cm in diameter and about 3 cm wide, worn on the head (Figure 1). This placed the band about 30 cm from the eye. There were 6 sets of light-emitting diodes (LEDs) on each side, with a red and a green LED in each set. The first set of LEDs on each side made an angle of 54 deg with the line of sight directly to the front. The first five sets of LEDs were 9 deg visual angle apart, so that the second set made an angle of 63 deg with the line of sight, the third set made an angle of 72 deg, and so on. The last set of LEDs was only 6 deg from the adjacent set and made an angle of 96 deg with the line of sight to the front.

Figure 1(A). The perimeter was worn on the subject's head. Red or green LEDs were illuminated along the extreme periphery.

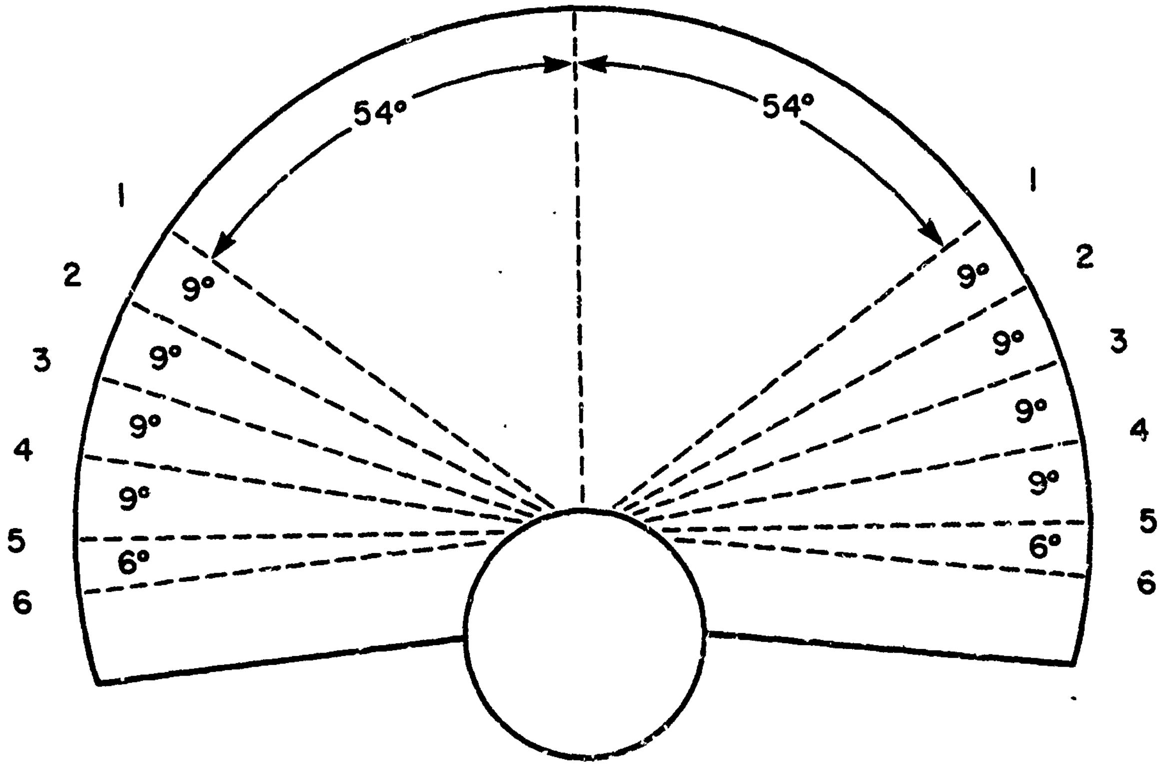

Figure 1(B). Diagram of the perimeter.

The visual fields were measured under ordinary room illumination. The subject was instructed to fixate a white dot on the band directly in front of him. The red stimuli were presented first. At irregular intervals, an LED at one of the positions would be flashed very briefly, and the subject responded "left" or "right" if he saw it. Only those positions which bracketed the limits of the subject's field of view were presented. Each of these was presented at least five times, but as many as 10 times if the subject's responses were unsystematic. The procedure was then repeated for the green stimuli. The frequency with which the light at each position was seen was calculated for each color. This relationship was plotted on cumulative probability paper; the thresholds were the 50% points on the plots for each color.

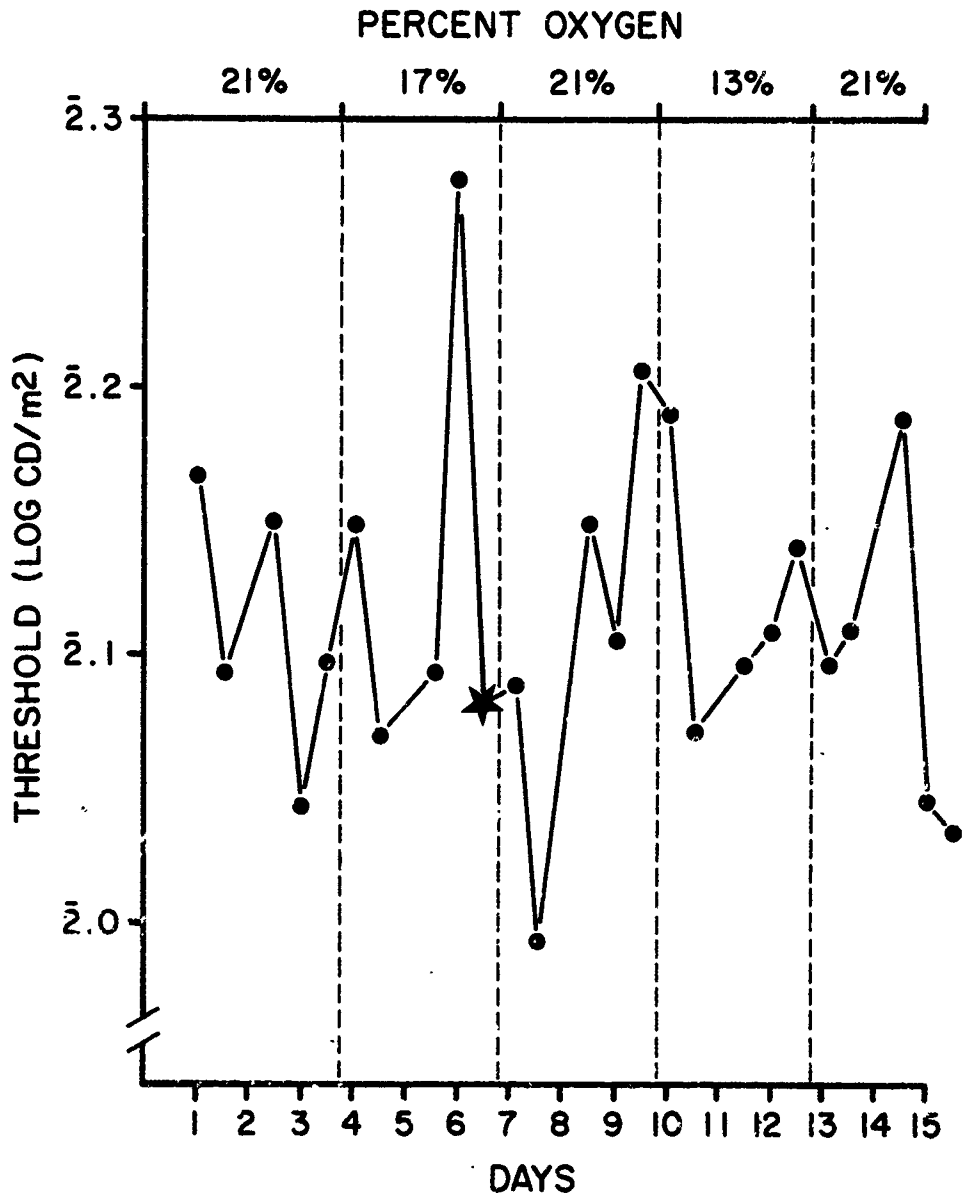

Figure 2. Mean scotopic thresholds for each test session. The higher numbers indicate an increase in sensitivity. The star for the last data point under 17% oxygen indicates the data obtained under a partial vacuum.

RESULTS

Scotopic Sensitivity

The data for the two groups of subjects were combined. Figure 2 shows the mean scotopic thresholds for each testing session during 15 days of confinement. There is no indication of a drop in sensitivity when the oxygen level is lower. Indeed, the lowest value occurs on the seventh day when the oxygen level was normal. The highest value occurs on the sixth day when the oxygen level was 17%. The final threshold in the 17% condition was obtained under the partial vacuum (the star in Figure 2). It is not unduly poor either in comparison with the other thresholds under 17% oxygen or in comparison with the thresholds for the entire study.

Figure 3 shows the mean thresholds under each oxygen level. Again, there is no evidence of a degradation of sensitivity when the oxygen level is lowered.

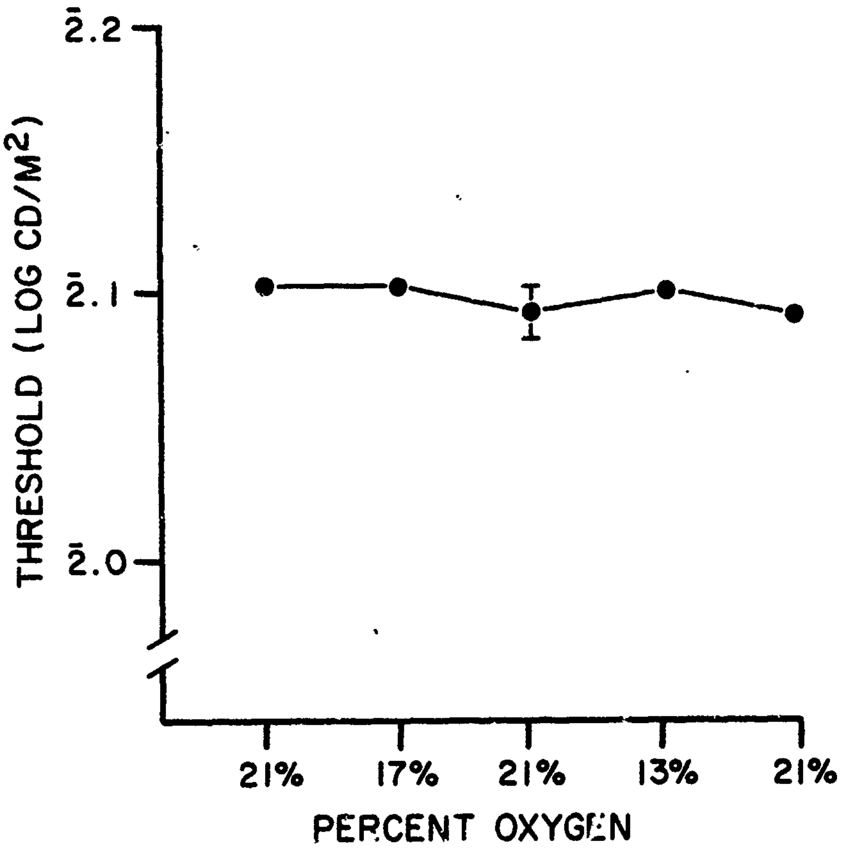

Figure 3. Mean scotopic thresholds for each oxygen level. The vertical line is the standard error of the mean.

To test the differences in threshold for statistical significance, the thresholds during each level of oxygen were averaged for each subject, producing, of course, five mean thresholds for each man. These values were then subjected to a one-way repeated measures analysis of variance. The differences were not significant ($F(4,48) = .32$).

To see if there were any differences during the course of the exposure to a given oxygen level, we compared the first thresholds obtained during exposure to each oxygen level (that is, after about three hours of exposure) with the final thresholds obtained in that condition (that is, after about 52 hours). Figure 4 shows the results. There is no indication that either of the reduced oxygen levels degraded scotopic sensitivity; nor did continued exposure to the reduced oxygen lead to any degradation or improvement in sensitivity. Again it may be noted that under 17% oxygen, the mean threshold was better at the end of the condition, under the partial vacuum.

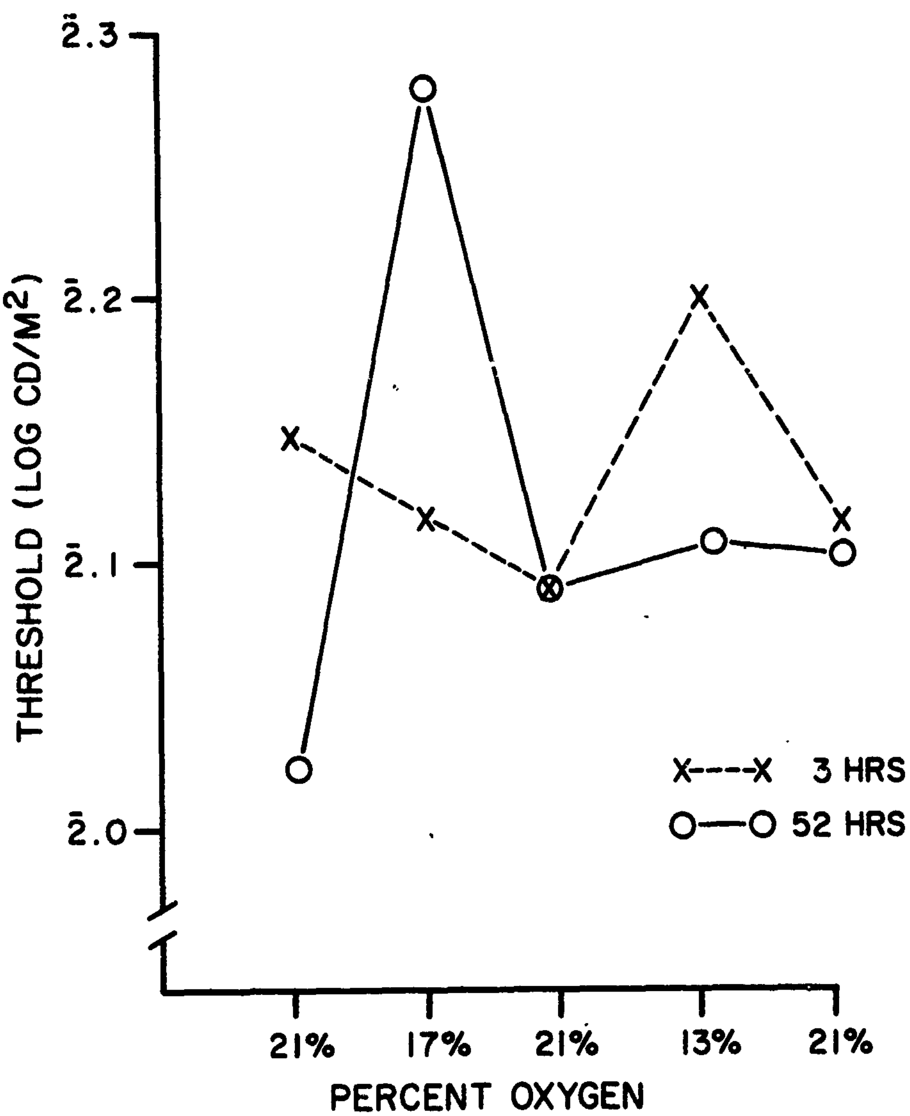

Figure 4. Mean scotopic thresholds measured at the beginning and at the end of each oxygen condition.

Field-of-View

The results for the perimetric measure are given only for the second group of seven subjects. The perimeter was damaged during the first phase of the study and not repaired for several days. Only incomplete data are available for the first phase of the study. Figure 5 shows the mean perimetry thresholds for each color in each condition during the second phase. In contrast to the scotopic data, these thresholds improve significantly ($F(4,24) = 6.75$, $p < .01$) during the course of the study, according to a one-way repeated measures analysis of variance. But there were no apparent degradations in the field of view when the oxygen level was reduced. The statistical significance stems solely from the continued improvement in the thresholds during the study; there were no significant differences between the low oxygen conditions and the adjacent 21% conditions. And there were no differences between the colors.

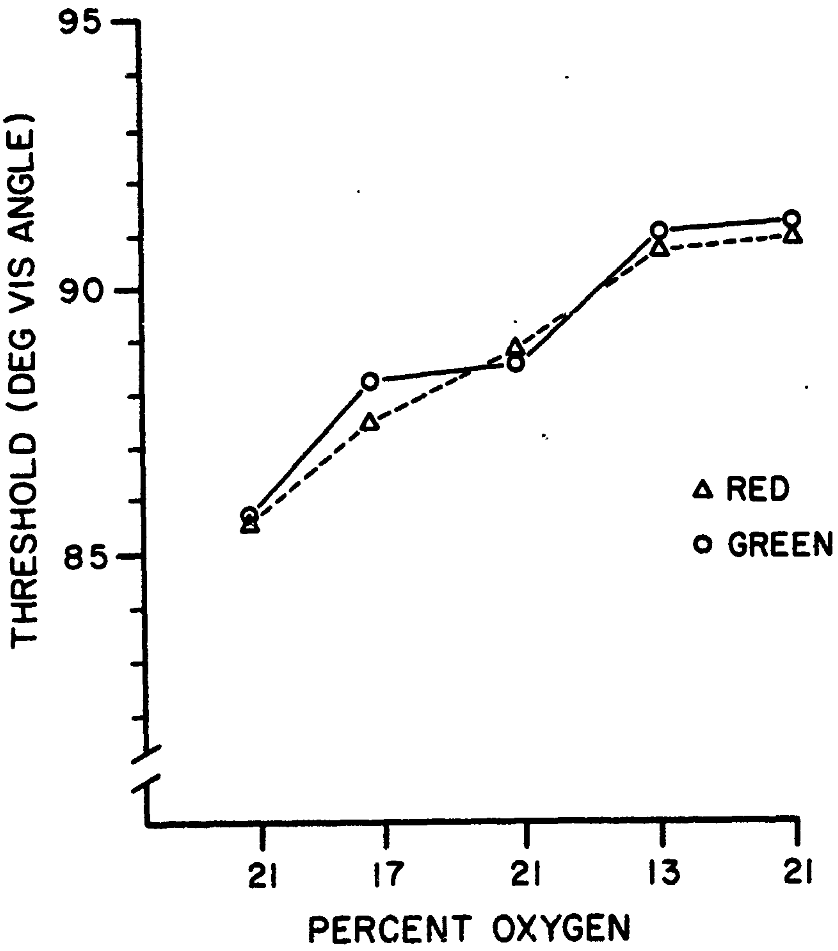

Figure 5. Mean perimetry thresholds for the green and red stimuli for each oxygen condition during the second phase of the study.

Although the data for each testing session are not shown, the mean thresholds during the partial vacuum under 17% oxygen were not degraded. The mean threshold for the two colors was, in fact, better than all but one of the other thresholds in that condition.

Figure 6 shows the mean perimetry thresholds during each condition at the beginning and end of the exposure to each oxygen level. Again there does not appear to be either a cumulative effect of hypoxia or an improvement resulting from adaptation to the exposure condition.

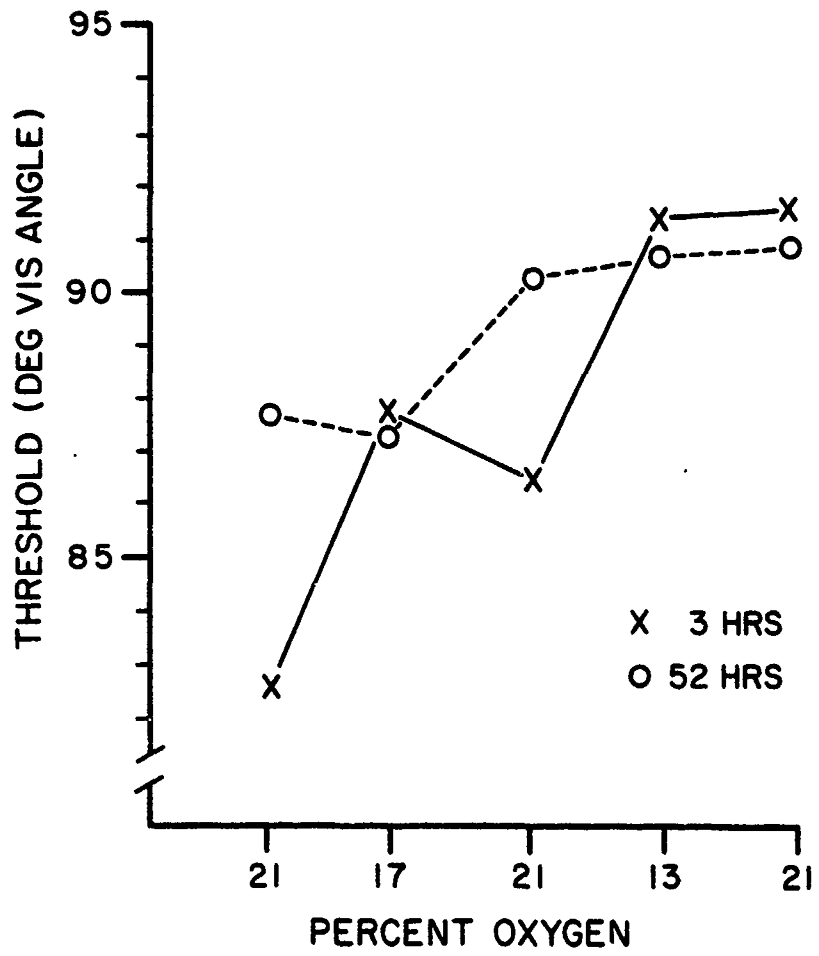

Figure 6. Mean perimetry thresholds measured at the beginning (after 3 hours of exposure) and at the end (after 52 hours of exposure) of each oxygen condition during the second phase of the study.

DISCUSSION

Previous Studies of Visual Sensitivity under Hypoxia

It has been suggested that change in visual function may be the most sensitive measure of oxygen deprivation (Halperin, et al., 1947; Carr, et al., 1966; Crews, 1966). Several mountain climbers have commented on the noticeable dimming of vision under conditions of hypoxia (e.g., Hornbein, 1983; Griffith, et al., 1983).

There has, however, been a notable lack of agreement among investigators as to the level of oxygen deprivation at which visual thresholds-- or other measures-- are affected. McFarland and his colleagues (1970) reported degradations of visual thresholds at altitudes of less than 5,000 feet, when arterial oxygen saturation was decreased less than 5%. Pretorius (1970) reported a significant improvement in night vision at an altitude of 5,000 when he administered 100% oxygen. On the other hand, a number of subsequent investigators found no significant changes in visual measures at carboxyhemoglobin levels of as much as 20%, corresponding to an altitude of 15,000 feet (Beard and Grandstaff, 1970; Stewart et al., 1970; Weir et al., 1973; Roche et al., 1981).

In our previous studies, we have not found decrements in the scotopic sensitivity of subjects exposed for three hours to 200 ppm of carbon-monoxide resulting in a COHb level of about 13% (Luria and Schlichting, 1979) or of subjects breathing air containing only 13% oxygen for three hours (Knight et al., 1987). We have found scotopic sensitivity to be affected only after the oxygen level in air was reduced to 10% (Luria and Knight, 1987).

Previous Studies of Field-of-View

It has also been widely reported that the limits of the visual field are decreased by anoxia (Halstead, 1945; Harrington, 1971). Kobrick, in a long series of studies (see Kobrick, 1976), showed that detection of peripheral stimuli was degraded as altitude increased, although his studies may indicate a degradation more of vigilance and reaction-time to peripheral stimuli than a decline in actual sensitivity. In a similar vein, Putz (1979) concluded that the demands of the task must be taken into account. Birren et al (1946) found that reaction-time declined at altitude, but found no significant changes in the perimetric measures even at 18,000 ft. which reduces the partial pressures of oxygen to half normal.

A considerable number of studies have investigated the effects of anoxia on the visual fields for different colors, also with contradictory results (Tune, 1964). An older study (Blum and Fisher, 1942) reported that anoxia affected the perception of red and green more than that of blue or white. Kobrick (1970) reported that sensitivity to red was affected the earliest and most severely. Most studies, however, have found that anoxia degrades the perception of green rather than red (Vollmer, et al, 1946; Schmidt and Bingel, 1953; Weitzman, et al. 1964; Smith, et al, 1976; Modugno, 1982).

The Present Study

There was no indication in the present results of any deleterious effect of hypoxia on either scotopic sensitivity or field of view. Indeed, the biggest drop occurred near the midpoint of the study when the oxygen level was normal. The subjects knew that their confinement was about half over, and they were permitted to stay up later than usual to have a mid-point celebration. This apparently had a much greater effect on the test results than did the reduction in oxygen.

When the mean values for each condition are considered, the only significant decline in scotopic sensitivity occurred during the final condition which, again, was a normal level of oxygen. This may best be explained by the sailor's term, "channel-fever". Knowing that the experiment was nearly over, the subjects may have begun to lose some of the motivation and concentration.

We conclude that a reduction of the percentage of oxygen in the breathing mixture to 13% does not degrade vision. As in our previous studies (cf. Luria and Knight, 1987), these results do not support the conclusion that vision is especially sensitive to small reductions in the level of oxygen. Rather they support the findings that rather sizable reductions in oxygen are required to degrade vision (Gellhorn, 1936; Otis, 1946; Tune, 1964; Pierson, 1967; Fowler, 1985).

REFERENCES

Beard, R.R. and Grandstaff, N. (1970). Carbon monoxide exposure and cerebral function. In: Coburn, R.F. (Ed.) Biological Effects of Carbon Monoxide. Ann. N.Y. Acad. Sci. 174: 385-395.

Blum, H.F. and Fisher, M.B. (1942). Measurement of "visual" fields with the perimeter under conditions of physiologic stress. NMRL Rep. No. 1, Bethesda: Naval Medical Research Laboratory.

Birren, J.E., Fisher, M.B., Vollmer, E., and King, B.G. (1946). Effects of anoxia on performance at several simulated altitudes. J. Exp. Psych. 36: 35-49.

Carr, R.E., Gouras, P., and Gunkel, R.D. (1966). Chloroquine retinopathy: early detection by retinal threshold test. Arch. Ophthalmol. 75: 171-178.

Crews, S.J. (1966). The prevention of drug induced retinopathies. Trans. Ophthalmol. Soc. UK 36:63-76.

Fowler, B., Paul, M., Porlier, G., Elcombe, D.D., and Taylor, M. (1985). A re-evaluation of the minimum altitude at which hypoxic performance decrements can be detected. Ergonomics 28: 781-791.

Gellhorn, E. (1936). The effects of 02-lack, variations in the CO2-content of the inspired air, and hyperpnea on visual intensity discrimination. Am. J. Physiol. 115: 679-684.

Griffith, L., Pugh, C.E., and sutton, J.R. (1983). Everest then and now. In: J.R. Sutton, C.S. Houston, and N.L. Jones (Eds.), Hypoxia, Exercise, and Altitude, New York: Alan R. Liss, Inc., pp. 415-428.

Halperin, M.H., Niven, J.I., McFarland, R.A., and Roughton, F.J.W. (1947). Variations in visual thresholds during carbon monoxide and hypoxic anoxia. Fed. Proc. (Abs.) 6: 120-121.

Halstead, W.C. (1945). Chronic intermittent anoxia and impairment of peripheral vision. Science 101: 615-616.

Harrington, D.O. (1971). The Visual Fields (3rd Ed.) St . Louis: Mosby.

Hornbein, T.F. (1983). Everest without oxygen. In: J.R. Sutton, C.S. Houston, and N.L. Jones (Eds.), Hypoxia, Exercise, and Altitude, New York: Alan R. Liss, Inc., pp. 409-414.

Knight, D.R., Luria. S.M., and Socks, J.F. Effects of low levels of oxygen on visual performance (in preparation).

Kobrick, J.L. (1970). Effects of hypoxia and acetazolamide on color sensitivity zones in the visual field. J. App. Physiol. 28: 741-747.

Kobrick, J.L. (1976). Effects of prior hypoxia exposure on visual target detection during later more severe hypoxia. Percept. Mot. Skills 42: 751-761.

Luria, S.M. and Knight, D.R. (1987). Scotopic sensitivity with 10% oxygen. NSMRL Rep. No. 1097. Groton, CT: Naval Submarine Medical Research Laboratory.

Luria, S.M. and Schlichting, C.L. (1979). Effects of low levels of carbon monoxide on vision or smokers and nonsmokers. Archiv. Environ. Hlth. 34: 38-44.

McFarland, R. (1970). The effects of exposure to small quantities of carbon monoxide on vision. Ann. N.Y. Acad. Sci. 174: 301-312.

Modugno, G.C. (1982). Variazioni del senso cromatico in corso di prolungata permanenza a m. 4.550 s.l.m. Riv. Med. Aeronaut. Spaz. 47: 247-253.

Otis, A.B., Rahn, H., Epstein, M.A., and Fenn, W.O. (1946). Performance as related to composition of alveolar air. Am. J. Physiol. 146: 207-221.

Pierson, W.R. (1967). Night vision and mild hypoxia. Aerosp. Med. 38: 993-994.

Pretorius, H.A. (1970). Effect of oxygen on night vision. Aerosp. Med 41:560-562.

Putz, V.R. (1979). The effect of carbon monoxide on dual-task performance. Hum. Fact. 21: 13-24.

Roche, S., Horvath, S.M., Gliner, J.A., Wagner, J.A., and Borgia, J. (1981). Sustained visual attention and carbon monoxide: Elimination of adaptation effects. Hum. Fact. 23: 175-184.

Schmidt, I. and Bingel, A.G.A. (1953). Effect of oxygen deficiency and various other factors on color saturation thresholds. USAF SAM Proj. No. 21-31-002, Randolph Field, Texas: US Air Force School of Aviation Medicine.

Smith, V.C., Ernest, J.T, and Pokorny, J. (1976). Effect of hypoxia on FM-100 Hue Test performance. Mod. Prob. Ophthalmol. 17: 248-256.

Stewart, R.D., Peterson, J.F., Baretta, E.D., Bachland, R.T., Hosko, M.J., and Hermann, A.A. (1970). Experimental human exposure to carbon monoxide. Arch. Environ. Hlth. 27: 155-160.

Tune, G.S. (1964). Psychological effects of hypoxia: review of certain literature from the period 1950 to 1963. Percept. Mot. Skills 19: 551-562.

Vollmer, E.P., King, B.G., Fisher, M.B., and Birren, J.E. (1946). The effects of carbon monoxide on three types of performance at simulated altitudes of 10,000 and 15,000 feet. J. Exp. Psychol. 36: 244-251.

Weir, F.W., Rockwell, T.H., Mehta, M.M., et al., (1973). An investigation of the effects of CO in humans on the driving task. Columbus OHIO: Ohio State University Research Foundation.

Weitzman, D.O., Kinney, J.A.S., and Luria, S.M. (1969). Effect on vision of repeated exposure to carbon dioxide. NSMRL Rep. No. 566. Groton, Connecticut: Naval Submarine Medical Research Laboratory.

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